Incidental Versus Ambient Visualizations: Comparing Cognitive and Mechanical Tasks

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***Abstract*—Incidental visualizations allow individuals to access information on-the-go, at-a-glance, and without needing to consciously search for it. Unlike ambient visualizations, incidental visualizations are not fixed in a specific location and only appear briefly within a person's field of view while they are engaged in a primary task. Despite their potential, incidental visualizations have not yet been thoroughly studied in current literature. We conducted exploratory research to establish the distinctiveness of incidental visualizations and to advocate for their study as an independent research topic. We tested both incidental and ambient visualizations in two separate studies, each involving one specific scenarios: a cognitively demanding primary task (42 participants), and a mechanical primary task (28 participants). Our findings show that in the cognitively demanding task, both types of visualizations resulted in similar performance. However, in the mechanical task, ambient visualizations led to better results compared to incidental visualizations. Based on these results, we argue that incidental visualizations should be further explored in scenarios involving physical requirements, as these situations present the greatest challenges for their integration.**

***Index Terms*—information visualization, incidental visualization, ambient visualization, user study**

I. Introduction

In today's information-centric world, effortless access to relevant information has become increasingly crucial. As individuals engage in various tasks, they encounter a multitude of data and information that require processing and understanding. However, the challenge lies in ensuring that accessing this information does not detract from the main task.

Ambient visualization [1] refers to a type of data visualization designed to present information subtly and non-intrusively. Its key feature is the seamless integration with the user's environment, offering background displays of data without causing distractions or requiring active engagement. The main goal of Ambient Visualization is to allow users to access relevant information effortlessly while maintaining focus on their primary tasks or activities.

Several sources have contributed to the development of ambient visualizations, including ubiquitous computing [2] and information visualization [3]. It is also related to calm technology [4], which seamlessly integrates into our lives without demanding excessive attention. Examples of ambient visualizations can be found in our homes, such as visualizations showing information about energy consumption and temperature [5], [6], or in enhancing the museum experience. One such example could be a dashboard displayed in a room, where users interact to change the visualization [7].

Recently, several studies have emerged that focus on Incidental Visualizations [8]–[10]. Incidental Visualizations are a type of visualization that presents information within one's field of view for a brief exposure time, without the individual actively seeking it. In other words, the information is not received on-demand. This allows users to access information effortlessly, without the need for active interaction or attention.

While Incidental Visualizations may share similarities with ambient visualizations, such as both being glanceable, there is a significant distinction. Incidental Visualizations only appear during the execution of a task and are not requested by the user, unlike ambient visualizations, which are intentionally sought and continuously available. For example, let us imagine we want to monitor the state of four machines via a bar chart because, depending on the values, we may take action. However, we do not have the time to just sit and look at the bar chart, as we have ongoing tasks that need to be completed. Therefore, an ambient visualization may not be the best option. Instead, we could have an incidental visualization appearing in our field of view occasionally so that we can keep track of the information without having to physically stop the current task to get it.

While it might seem intuitive that Ambient Visualizations and Incidental Visualizations differ in use cases and characteristics, there has been little formal confirmation due to a scarcity of academic research directly comparing the two. As a result, it is uncertain whether they are perceived similarly under comparable conditions. This study empirically aims to explore these topics by investigating and comparing the perception of Ambient Visualizations and Incidental Visualizations in two task scenarios. We want to address the following research questions within this context, considering one task that is more cognitively demanding and another that is more mechanical:

- **RQ1**: Is the information displayed in Incidental Visualizations as effective as with in Ambient Visualizations?
- **RQ2**: Which visualization type is more suitable for a scenario with a mentally demanding primary task? And which is more suitable for a mechanically demanding primary task?

II. Related Work

In this section, we will briefly explore the concepts of ambient visualization and incidental visualizations. Following this, we will discuss how our work aligns with the current state of the art.

A. Ambient Visualizations

At the root of ambient visualizations lies the concept of calm technology, which is an approach to designing devices and systems that seamlessly integrate into our daily lives, enhancing human capabilities without demanding constant attention. Pioneered by Mark Weiser and John Seely Brown [4], [11], this concept emphasizes technology that moves effortlessly between the periphery and center of our awareness, providing necessary information without causing distraction.

Ambient information visualizations, inheriting from calm technology, are an innovative approach to displaying data in a subtle and non-intrusive manner, seamlessly integrating into the user's environment [3], [12], [13]. By presenting information on the periphery of our attention, they allow us to remain focused on primary tasks while staying informed through intuitive visual cues. These visualizations are designed to be contextually relevant [6], adapting to the user's surroundings and needs [14], and may be often embedded in everyday objects like ambient light displays [15] or dynamic wall art [16]. The key lies in their ability to convey important information gently and aesthetically [17]–[19], ensuring updates are smooth and non-disruptive. This approach enhances our situational awareness and promotes a more harmonious and less distracting interaction with technology.

Recently, for example, Hammady et al. [20] utilized the Microsoft HoloLens to deploy an ambient information visualization in a museum, which most users found highly engaging and easy to use. Furthermore, Raudanjoki et al. [15] employed shadows to display illustrative bird images and other relevant visuals as an ambient display. Morrison-Smith et al. [21] aimed to enhance team awareness in remote work environments by using an ambient display to show activity related to the files of a team project, thereby helping collaborations maintain a sense of the team's involvement while working remotely. Ulrike Hahn and Pauwke Berkers [22] explored the effectiveness of artistic information visualizations in communicating climate change. Lastly, Thompson et al. [23] designed and implemented AmbiDots, an ambiguity-centric ambient system that uses subtle, colored dots to support peripheral playful interactions in social settings such as cafes, restaurants, or bars.

In recent years, several related topics have been explored, inspired by ambient visualizations. Joshi et al. [24] introduced a new design framework for creating information visualizations in spatial augmented reality environments. Blascheck et al. [25] examined glanceability as a crucial requirement for various types of mobile visualizations, integrating insights from Vision Sciences, Visualization, Human-Computer Interaction, and Ubiquitous Computing. Bressa et al. [26] conducted a comprehensive survey and analysis of situated visualization, an emerging concept in information visualization that focuses on visualizing data in situ, where it is relevant to people. Han et al. [27] developed DataHalo, a customizable notification visualization system that represents notifications as prolonged ambient visualizations on the smartphone home screen.

B. Incidental Visualizations

Due to the topic's novelty, there are not many studies in the current literature about incidental visualizations. In 2020, Moreira et al. [8] took the first step in exploring these visualizations. They investigated the concept of pre-attentive visual tasks within the context of incidental visualizations, and concluded that position was the channel that was perceived the most accurately.

In 2023 [10], they conducted to understand the influence of incidental visualizations on the performance of a primary task. The researchers explored how these visualizations affect the time required to complete the primary task, the quality of information perceived by users, and the cognitive load induced by their presence. The results suggest that introducing a visualization in a primary task has a minimal impact on all three factors mentioned.

Finally, in 2024, the authors [9] revisited the exploration of graphical perception [28]. Their study delved into how various types of visual marks (such as position, length, and angles) and the duration of display in a visualization affect the accuracy of incidental perception while engaged in a primary task. The findings of the study suggest that incidental graphical perception can be precise when utilizing position, length, and angles as visual channels.

C. Discussion

Ambient displays and incidental visualizations share similarities in their definition, being seen at-a-glance and on-the-go. However, while the current literature provides a solid definition of ambient visualizations, incidental visualizations still lack an exact definition. Since this work aims to explore and demonstrate the differences in specific metrics between these two concepts, we propose a precise definition of incidental visualizations based on our literature review. **"Incidental visualizations empower individuals to effectively access information on-the-go, at-a-glance, and while engaged in primary tasks, without the requirement for conscious searching, thereby encompassing tasks that may be otherwise incompatible with conventional information visualization methods."**

This definition highlights the most significant difference between incidental and ambient visualizations: conscious searching. Incidental visualizations are not actively sought out; instead, they present themselves to the user. Therefore, we assume that users are always engaged in a primary task when encountering incidental visualizations. This distinction motivated us to conduct this exploratory work in hopes of paving the way for a clear research topic. In the next section, we will explain our two user studies.

III. METHOD

The objective of our work was to explore ambient and incidental visualizations in two distinct scenarios with differing participant requirements, following a between subjects user study design; ensuring participants were not biased by participating in the other user study. In the first scenario, the primary task was cognitively demanding. In the second scenario, the primary task focused on mechanical aspects. In both scenarios, we aimed for the primary task to capture the participants' attention, leaving little opportunity to focus on the visualization display. Additionally, for each scenario, we tested three different visual idioms (bar chart, line chart, and donut chart) to determine if any of them led to better task performance and perception accuracy. We chose these charts because they were previously used in research involving incidental visualizations [8], [10].

A. First User Study — Cognitive Task

The study was designed as a between-subjects experiment with two groups of participants, each assigned to perform the same three primary tasks. One group was placed in the ambient visualization condition, and the other in the incidental visualization condition. For both groups, the primary task involved watching three videos, one at a time, with a visualization displayed beside them. Each video featured a different visual idiom in the corresponding visualization.

While watching each video, participants were instructed to keep track of two things in real-time: the number of times a specific word was spoken by the video's narrator and the frequency of a particular visual element appearing throughout the video's duration. Additionally, participants answered questions about the visualization on a provided sheet. This process was repeated for the two other videos. The study featured only one independent variable: the type of visualization used during the tasks, either ambient or incidental.

The study included several dependent variables: the number of words counted in the audio portion of the video; the number of visual elements counted in the visual portion of the video; and the effectiveness of visualization perception, measured by participants' answers to questions about the visualizations.

The study was conducted in a controlled environment with a 1080p monitor and two speakers. The monitor was placed on a desk where participants had access to an answer sheet and a pen. They used these tools to count words and visual elements, as well as to respond to questions about the visualizations.

The tablet was positioned horizontally on a stand to the right of the monitor (Figure 1), displaying either the ambient visualization or the incidental visualization. This placement ensured that the visualizations were within the participants' field of view. While an ambient visualization might not always be within the field of view, we assumed that incidental visualizations would be. To facilitate a fair comparison between both types, we displayed them in the same location on the same device.

Participants watched a video alongside one of the visualizations three times, each with a theme centered around the car industry. During the study, they were asked to record their counts of a specific word and a visual element on an answer sheet. To ensure accuracy and prevent reliance on memory, this recording had to be done while they were watching the videos.

Fig. 1. Setup of the first user study.

To control for potential order effects, the study used a Latin square design to determine the sequence in which participants viewed the videos and their corresponding visualizations. The videos were labeled with the last three letters of the alphabet (X, Y, Z), while the visualizations were labeled with the first three letters of the alphabet (A, B, C). Participants were then assigned specific tasks to complete while watching the different videos.

Video X:

- **Word**: Listen for instances of the Portuguese word "**um**". The word was spoken by the narrator a total of two times.
- **Visual Element**: Count the number of times that a **bus** appeared in the images shown throughout the video. A total of two buses appeared in the images.

Video Y:

- **Word**: Listen for instances of the Portuguese word "**primeiro**". The word was spoken by the narrator a total of two times.
- **Visual Element**: Count the number of times that **bicycles** appeared in the images. A total of two bicycles were present in the images.

Video Z:

- **Word**: Listen for instances of the Portuguese word "**dispositivo**". The word was spoken by the narrator a total of two times.
- **Visual Element**: Count the number of times that **crosswalks** appeared in the images. One crosswalk was present in the images.

During the study, participants were presented with visualizations while watching videos. The ambient visualization was displayed continuously from the moment participants entered the room until they finished watching the videos. After completing a video, the ambient visualization was switched to the next one. In contrast, incidental visualizations appeared briefly on the tablet screen for only one second while the videos were playing. For each trial, we asked participants two questions about the visualizations.

The study aimed to investigate three distinct trials, each pairing a different video with a visualization. To prevent bias towards any specific visual style, we opted for three different visual idioms. These idioms, utilizing the same dataset sourced from [1], were selected to complement the theme of the videos. Specifically, we utilized bar charts (Figure 2a), donut charts (Figure 2b), and line charts (Figure 2c), all widely recognized in information visualization. Prior research [29], [30] has shown that participants find these idioms easy to comprehend and effective in conveying information. Bar charts are typically employed for representing data with discrete categories, donut charts for illustrating how a whole is segmented, and line charts for depicting trends over time.

Now, we will describe how we designed the visualizations. Each visual idiom was composed of four marks, based on previous research that determined the optimal number of marks for information perception in incidental visualizations [8]. This approach was inspired by the cognitive mechanism called subitizing [31], [32]. The colors used in all visualizations were chosen from a palette[2] to ensure even colorblind participants could distinguish them. Finally, the questions asked involved two visual tasks.

Bar Chart:

- The Bar chart was designed to represent the number of cars sold per brand in a given year.
- **Q1**: Find the highest value.
- **Q2**: Between B and C, which one has the smallest value?

Donut Chart:

- This Donut chart represented car colors with the most sales in the US.
- **Q1**: Find the highest value.
- **Q2**: Between A and C, which one has the highest value?

Line Chart:

- The Line chart represented the trend in car sales from 2014 to 2019 in the US.
- **Q1**: Find the highest value.
- **Q2**: Between C and B, which one is decreasing?

During the study, participants were given a five-second window to respond to questions regarding the visualizations. However, we refrained from explicitly informing them of this time limit to prevent any potential influence on their responses. Instead, we instructed them to answer the questions as promptly as possible. The rationale behind not disclosing the time constraint to participants was to assess their capacity to promptly perceive and interpret the data depicted in the visualizations without depending on memory.

B. Second User Study — Mechanical Task

Our second user study was to investigate how ambient visualizations and incidental visualizations impact user performance in a mechanical task. Participants were instructed to assemble Lego figures using physical pieces based on a reference image displayed on a tablet screen. Each participant completed three trials, with different figures and visualizations in each trial. The independent variable remained constant, while the dependent variables were the Lego Score and the time taken to assemble a figure. Visualizations were positioned strategically within participants' field of view to ensure their presence during the task.

The setup comprised a table with a selection of 35 Lego pieces. These included: eight red, eight blue, eight green, seven yellow bricks, and four flower-shaped pieces (one each in green, red, pink, and blue). Additionally, there were four pieces, each with four studs in the aforementioned colors, three pieces with eight studs in each color, and three larger pieces (one in blue, one in green, and one in red) with twelve studs each.

In front of the Lego pieces, a tablet stood vertically, showing the Lego figure participants needed to recreate (Figure 3). Beside the Lego pieces, we placed a pen and an answer sheet for participants to jot down their answers. Positioned to the right of the workspace, a screen displayed the visualization.

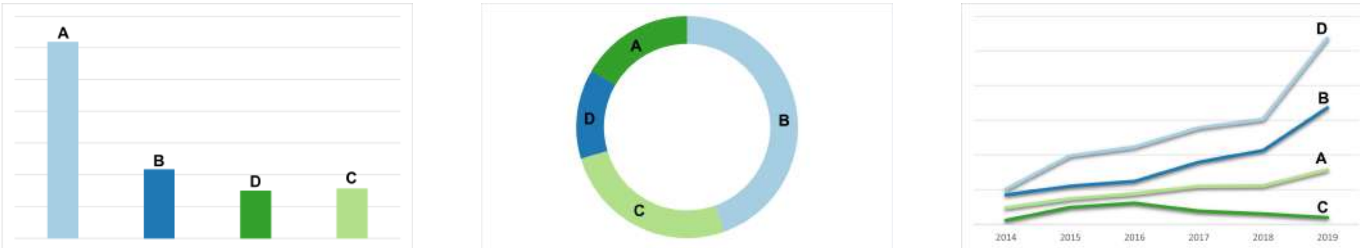
The participants were tasked with building three Lego figures within a fifty-second time limit, determined as optimal based on a preliminary study. This duration, along with the total of fourteen required pieces, was chosen deliberately to maintain participant engagement. The Lego figures, representing everyday objects and animals, were presented to participants on a tablet screen. A Latin square distribution, with figures labeled X, Y, Z, and visualizations labeled A, B, C, ensured a balanced sequence of encounters. The Lego figures are depicted in Figure 4.

After participants finished the Lego building task within the allocated fifty-second timeframe, we replaced the image on the tablet with a blank screen to indicate the task's end. Subsequently, we documented the duration each participant devoted to constructing their Lego figure. If any participant surpassed the time limit, we promptly informed them and asked them to halt their construction.

To evaluate the precision of their Lego constructions, we devised a clear-cut scoring mechanism. Each figure consisted of a total of fourteen components, with the highest attainable score capped at fourteen. The scoring standards revolved around the exact positioning of each component within the figure, ensuring its alignment with the specified type and color outlined in the reference model. For every component accurately assembled in terms of type and color, one point was added to the participant's score. Conversely, if a participant erroneously incorporated a component of an incorrect type or color, one point was deducted from their score. Additionally, any components absent from the figure due to the participant exceeding the time limit would not contribute to their score.

Participants were assigned the task of constructing Lego figures while simultaneously being presented with visualizations on a computer screen, similar to the previous scenario. These visualizations varied in terms of idioms, mirroring those utilized in the initial study and adhering to the same rationale and design principles. The visual idioms (refer to Figure 2)

[1]https://www.kaggle.com/datasets/tsaustin/us-used-car-sales-ata
[2]https://colorbrewer2.org/



(a) Bar Chart (b) Donut Chart (c) Line Chart

Fig. 2. Visual idioms used in both user studies.

employed are illustrated in Figures 2a, 2c, and 2b, with only the data varying.

Bar Chart:

- The Bar chart was designed to represent the number of cars sold per brand in a given year.
- **Q1**: Find the lowest value.
- **Q2**: Between A and B, which one has the smallest value?

Donut Chart:

- This Donut chart represented car colors with the most sales in the US.
- **Q1**: Find the highest value.
- **Q2**: Between B and C, which one has the lowest value?

Line Chart:

- The Line chart represented the trend in car sales from 2014 to 2019 in the US.
- **Q1**: Find the highest value.
- **Q2**: Between C and B, which one is decreasing?

In the second study, participants were once again provided with a five-second time limit to respond to questions regarding the visualizations. While the participants were not explicitly informed of this time constraint, they were strongly encouraged to provide prompt answers.

In the following section, we will provide a detailed analysis of the results obtained from both studies and emphasize the valuable insights gleaned from the collected data.

IV. Results and Discussion

In the initial study, a total of 42 participants engaged in all three trials. Their ages varied from 15 to 52 years, with 25 participants falling between 15 and 19 years old, 11 participants aged between 21 and 23, and six participants aged between 46 and 52. Of the total, 26 participants identified as male and 16 as female. The participants were evenly distributed, with 21 assigned to the incidental visualizations group and another 21 to the ambient visualizations group.

In the second study, we had 28 participants, all of whom successfully completed all three trials. The age of the participants spanned from 16 to 29 years, with 11 falling within the 16-19 age bracket and 17 within the 20-29 age bracket. Of the total, 24 identified as male and 4 as female. Each group, comprising 14 participants, was randomly assigned either to the incidental visualizations or ambient visualizations.

Both of our studies revolved around the independent variable of visualization type, consisting of two distinct groups: ambient and incidental. Our goal was to investigate the impact of these visualization types on various dependent variables.

In the first study, these dependent variables comprised audio task performance, visual task performance, first visualization answer, and second visualization answer.

In the second study, we included the visualization answers along with Lego accuracies and build times.

To analyze the responses to both visualization questions, we utilized the Test of Two Proportions. For the rest, we conducted the Mann Whitney-U Test. Detailed statistics can be found in Tables I and II. All the data analised can be found here: https://figshare.com/s/f3af914319c55aeec4c2.

A. Task Performance

In the initial study (refer to Fig. 5), participants' performance in the Audio Task showed no significant difference

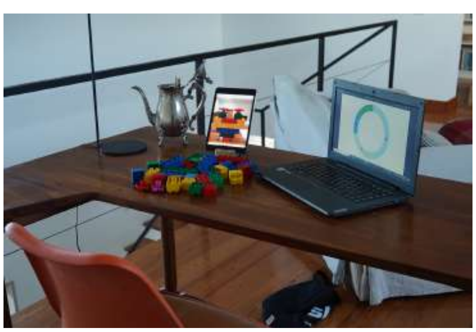
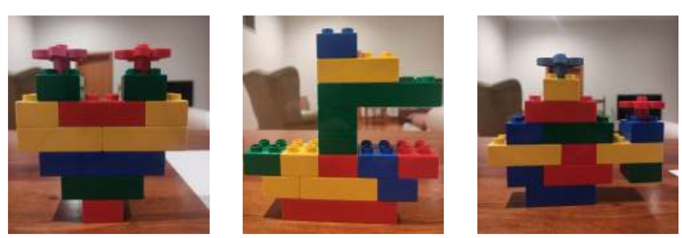


Fig. 3. Setup of the second user study.



(a) Figure X (b) Figure Y (c) Figure Z

Fig. 4. Lego figures that participants were required to build.

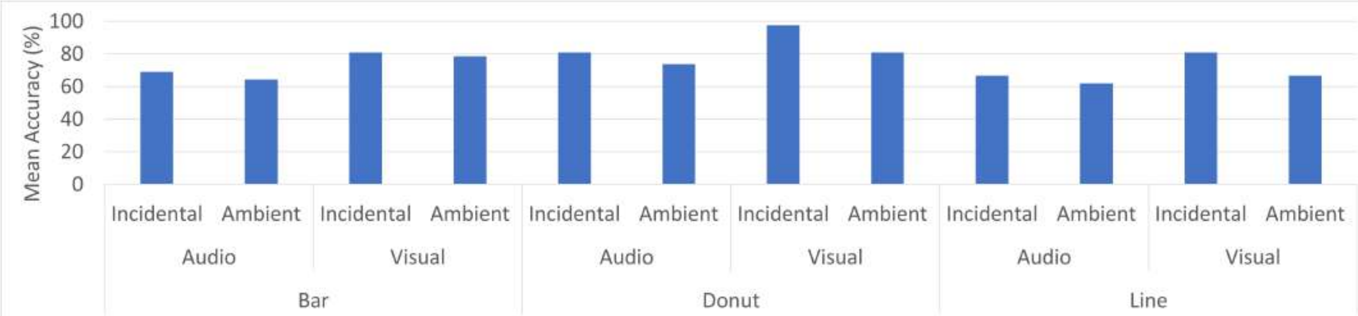


Fig. 5. Mean accuracy for the tasks performed in the first user study, categorized by type of visualization and visual idiom.

across all idioms utilized for ambient visualization. However, their average performance was lower when compared to the incidental visualization group, particularly evident when tested with the donut chart. As for visual task performance, both groups exhibited a median performance of one hundred percent. The only exception was observed in the ambient visualization group when the test involved the line chart, where the median dropped to fifty percent.

In examining the performance variables depicted in the second study (refer to Fig. 6), we found that the mean Lego Scores were consistent across both groups and visual idioms, with most participants attaining the maximum score of fourteen. However, upon analyzing the time required to complete the primary task, we observed a discrepancy. Specifically, participants in the ambient visualization group demonstrated quicker completion times when presented with bar and line charts. Conversely, when the visualization featured a donut chart, median completion times were comparable across both groups.

For the performance variables, we also performed a Mann-Whitney-U Test. None of the obtained p-values were statistically significant ($p < 0.05$) in either the first or the second study. This suggests that the distribution of variables remains consistent across both visualization types. Consequently, there was no significant difference observed between the two groups in terms of primary task performance in either study. Therefore, one can choose between an ambient visualization and an incidental visualization for executing primary tasks without compromising participants' performance. Next, we focus on the results related to the visualization tasks, which were carried out simultaneously with the primary tasks.

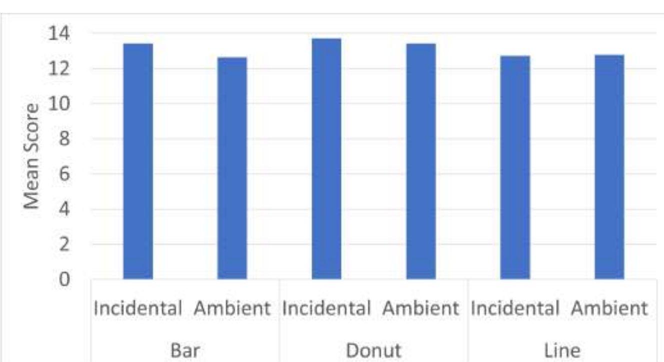


Fig. 6. Mean accuracy for the tasks performed in the second user study, categorized by type of visualization and visual idiom.

B. Visualization Answer Performance

In the initial study, ambient visualizations showed marginally higher correct answer rates across all charts. However, there was an exception in the first visualization question where participants in the incidental visualization group had a higher correct answer rate when presented with a donut chart. Notably, both bar and donut charts consistently outperformed the line chart in both questions. We conducted a Test of Two Proportions and found that none of the observed differences in proportions were statistically significant ($p < 0.05$), as shown in Table II. This suggests that when users are engaged in mentally demanding tasks that require focus on audio and video elements, the choice between these visualization types does not significantly affect answer accuracy.

Regarding prior studies involving incidental visualizations [8]–[10], while our work diverges in its premise (we're not aiming to understand the effect of visualizations on the primary task or to discern which encodings are more effective; instead, we're exploring the differences between types), we've noted similarities in our findings. In their 2020 and 2021 research, they discovered that length effectively encodes values in incidental visualizations, and in their 2021 study, they also noted the effectiveness of angle. Both the bar chart (utilizing length) and the Donut chart (employing both length and angle) demonstrated the highest levels of accuracy.

In the second study, the ambient visualization group displayed higher percentages across all visual idioms. After conducting a Test of Two Proportions, it was determined that there was no significant difference between the groups in terms of the results for the donut chart, as the findings did not reach statistical significance. Once again, our findings align with previous research on incidental visualizations [8]–[10], although the overall accuracy was not notably high. Notably, length and angle demonstrated the highest levels of accuracy.

In the case of the bar chart, all 14 participants (100%) in the ambient visualization group provided correct answers, while in the incidental visualization group, only 10 participants (71.4%) did so. The disparity in proportions was found to be statistically significant at .29, yielding a p-value of 0.049.

Likewise, concerning the line chart, 12 participants (85.7%) in the ambient visualization group answered the first question correctly, compared to only 6 (42.9%) in the incidental visualization group. For the second question, 12 participants (85.7%) in the ambient visualization group answered correctly, while only 5 (35.7%) in the incidental visualization group did so.

Based on these findings, it is evident that when employing a bar chart or a line chart in the visualizations, an ambient visualization is more appropriate for a mechanical task.

C. Summary

After thorough analysis of the collected data and rigorous statistical testing, several crucial findings have surfaced. When the primary task entails substantial cognitive demands, no significant discrepancy arises in selecting between the two visualizations. Thus, we assert that **an incidental visualization may be employed in such scenarios for discreet representation, whereas an ambient visualization can be opted for ensuring consistently accessible information**.

When participants engaged in a mechanical demanding primary task, they found ambient visualizations easier to perceive compared to incidental visualizations. This holds true regardless of the specific visual idiom employed, with minimal variance in perception observed across different idioms. However, when it comes to incidental visualizations, users faced notable challenges, especially with the line chart. Interestingly, the performance on primary tasks remains relatively consistent regardless of whether they are accompanied by ambient or incidental visualizations.

Summarizing, we were able to answer our two research questions:

- **RQ1**: Is the information displayed in Incidental Visualizations as effective as with in Ambient Visualizations? In the cognitive task, the answer is ”yes”, but in the mechanical task, ambient visualizations were overall more effective.
- **RQ2**: Which visualization type is more suitable for a scenario with a mentally demanding primary task? And which is more suitable for a mechanically demanding primary task? In the cognitive task, both are suitible, but in the mechanical task, ambient visualizations may usually be a better option.

V. Conclusions

The objective of this study was to compare two types of visualizations: incidental visualizations and ambient visualizations, in the context of executing both mentally demanding and mechanically challenging tasks. The aim was to empirically demonstrate that incidental visualization differs from ambient visualization and merits distinct study. The results indicate that in scenarios demanding both auditory and visual effort, either type of visualization can be employed. However, in scenarios involving mechanical effort, the use of ambient visualization offers a slight advantage. We therefore argue that incidental visualizations need to further explored in situations with physical requirements, as these situations prove the most challenging to incorporate them. Especially if there is no place or solution to have an ambient visualization and people still need to access information in real-time during a primary task.

A. Limitations and Future Work

A notable limitation of our study pertains to the specific scenarios and visualizations we tested. We concentrated on two distinct scenarios: one involving audio and visual effort, and the other involving mechanical and visual effort. Our comparisons were restricted to Ambient and Incidental Visualizations within these scenarios. Consequently, we cannot extend our conclusions to other scenarios differing from those we examined.

TABLE I
Statistical results for five of the studied variables are presented in this table. The left f and p values correspond to the first user study, while the right values correspond to the second study.

Variable	***f***	***p***	***f***	***p***
Bar Chart				
First	0.311	0.500	0.29	**0.049**
Second	0.142	0.343	0.36	0.060
Donut Chart				
First	0.634	0.500	0.29	0.104
Second	0.238	0.093	0.07	0.500
Line Chart				
First	0.286	0.107	0.43	**0.023**
Second	0.143	0.346	0.50	**0.009**

TABLE II
Statistical results for performance variables are presented in this table. The left f and p values correspond to the first user study, while the right values correspond to the second

Variable	***f***	***p***	**Variable**	***f***	***p***
Bar Chart					
Audio	236.5	0.651	Lego	102.5	0.795
Visual	224.5	0.905	Time	113.5	0.482
Donut Chart					
Audio	257	0.288	Lego	109	0.538
Visual	284	**0.019**	Time	104.5	0.769
Line Chart					
Audio	245	0.482	Lego	94	0.830
Visual	274	0.116	Time	119.5	0.319

Furthermore, our study was influenced by what is commonly known as the Toy Problem. This term typically refers to a simplified or idealized version of a real-world problem used for experimental purposes. For example, factors such as the positioning of visualizations, how individuals interacted with them, and the primary tasks involved, all represent instances where we simplified complexity to focus on our intended evaluation criteria. Our findings are specific to the scenarios we investigated and should be interpreted within that context.

Lastly, we did not assess the participants' characteristics in either study. We acknowledge that certain factors, such as demographic information, visualization literacy, prior experience with Lego building, video analysis skills, and cognitive traits like attention capacity, may have influenced the results.

We argue that our results provide motivation for further exploration, especially in the realm of Incidental Visualizations, which remains a relatively novel subject.

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